

(12) UK Patent Application (19) GB (11) 2 124 798 A

(21) Application No 8318972

(22) Date of filing  
13 Jul 1983

(30) Priority data

(31) 57/121564  
57/121565  
57/121566

(32) 13 Jul 1982

(33) Japan (JP)

(43) Application published  
22 Feb 1984

(51) INT CL<sup>3</sup> G05B 19/42

(52) Domestic classification  
G3N 286C 386 404 A  
U1S 1822 G3N

(56) Documents cited

GB 1473109  
GB 1403860

(58) Field of search  
G3N

(71) Applicant  
Kubota Ltd  
(Japan)  
47-go 2-ban 1-chome  
Shikitsuhigashi  
Naniwa-ku

Osaka-shi

Osaka-fu

Japan

(72) Inventors

Katsumi Ito  
Jitsuo Yoshida

(74) Agent and/or Address for

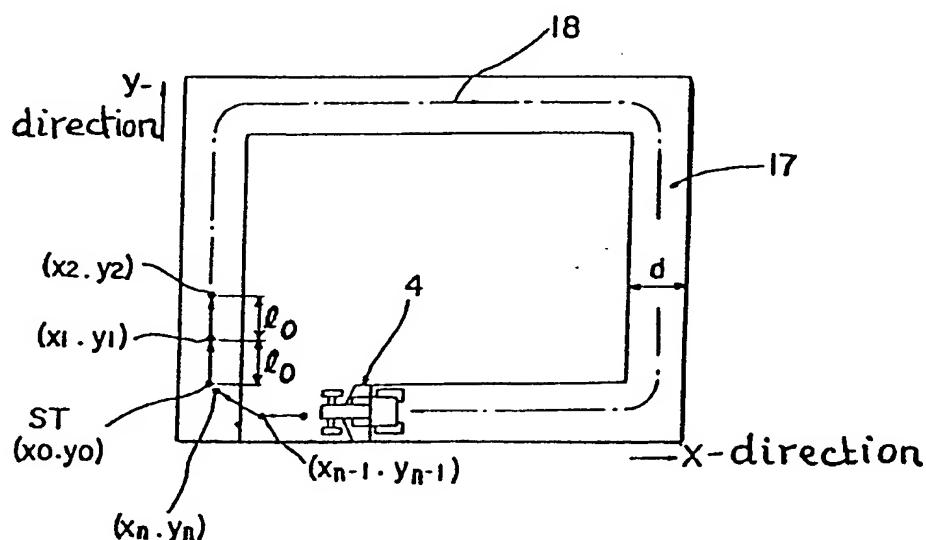
Service  
Baron & Warren  
18 South End  
Kensington  
London W8 5BU

(54) Automatic running work vehicle

(57) An automatically controlled vehicle eg a bulldozer, mower or sprinkler truck has a distance sensor for detecting the vehicle running distance, an orientation sensor 5 for detecting the running direction thereof, and a processing unit for teaching the running course of one travel of the vehicle by sampl-

ing the running direction detected by the orientation sensor every predetermined running distance detected by the distance sensor during the travel and for steering the vehicle based on the information of the running course obtained by the teaching of the preceding travel when the follower sensors 101 fail to detect the boundary for a predetermined period of time. The vehicle is taught by driving it round the edge of the area to be treated. It then covers the whole area inside this edge automatically.

Fig. 6 direction



GB 2 124 798 A

1/16

2124798

Fig. 1

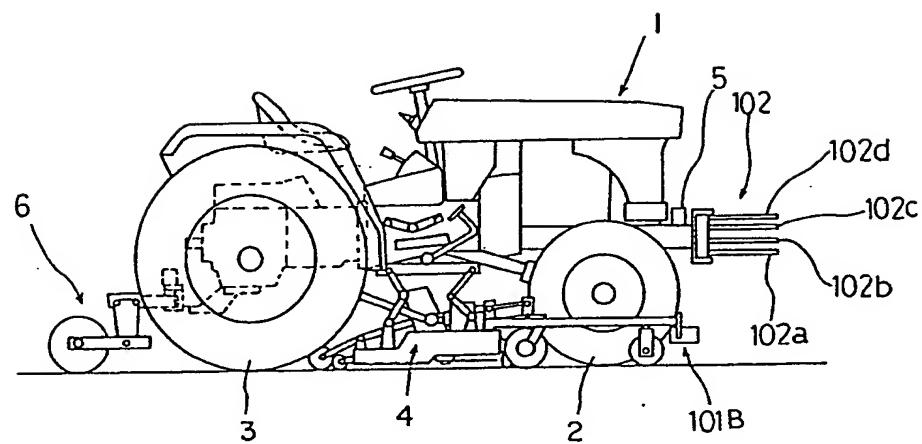
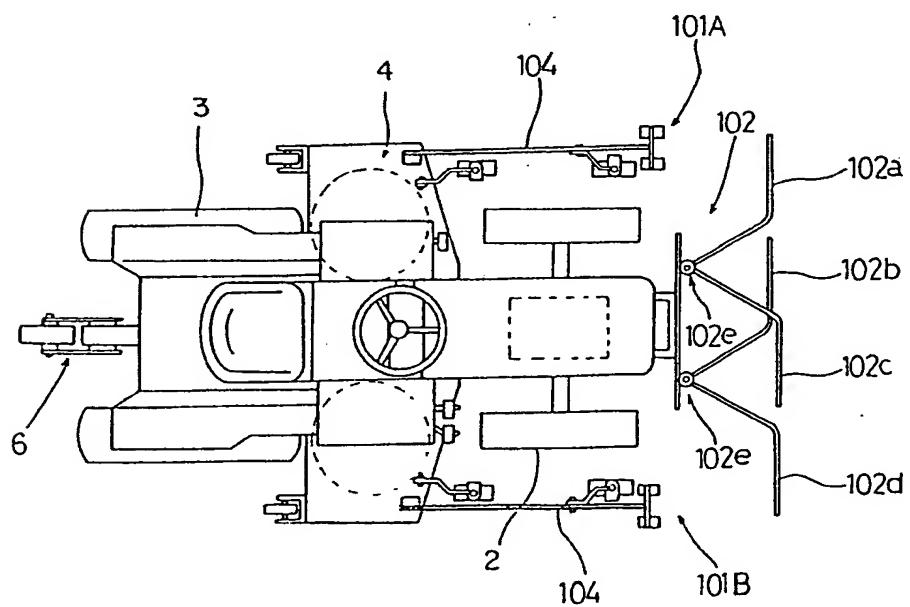


Fig. 2



2/16

2124793

Fig. 4

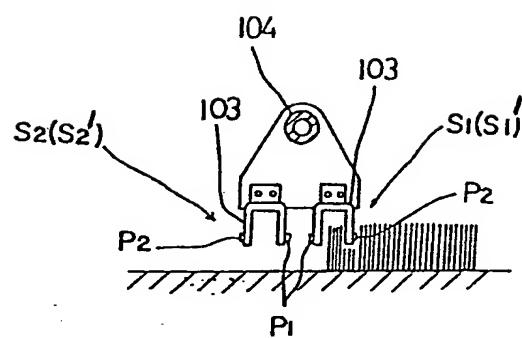


Fig. 3

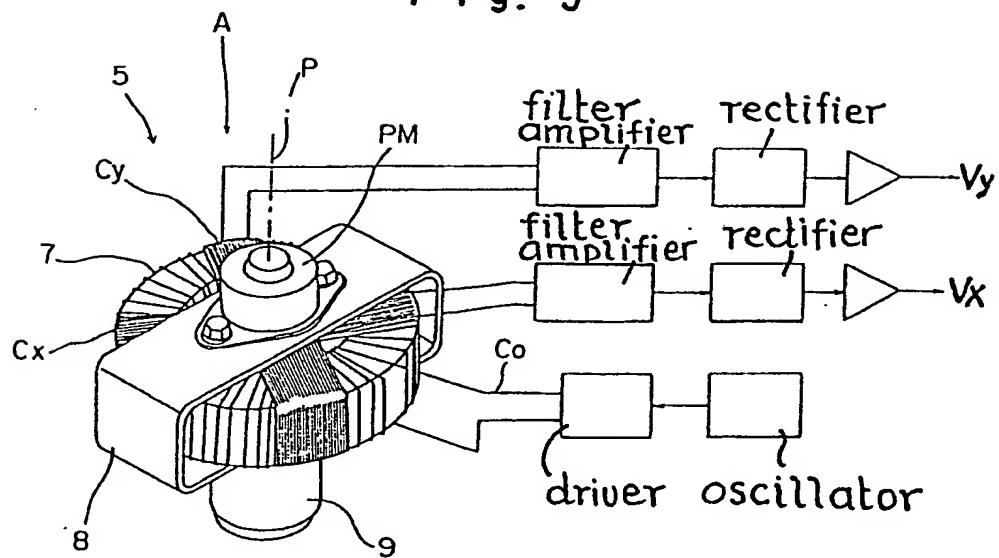
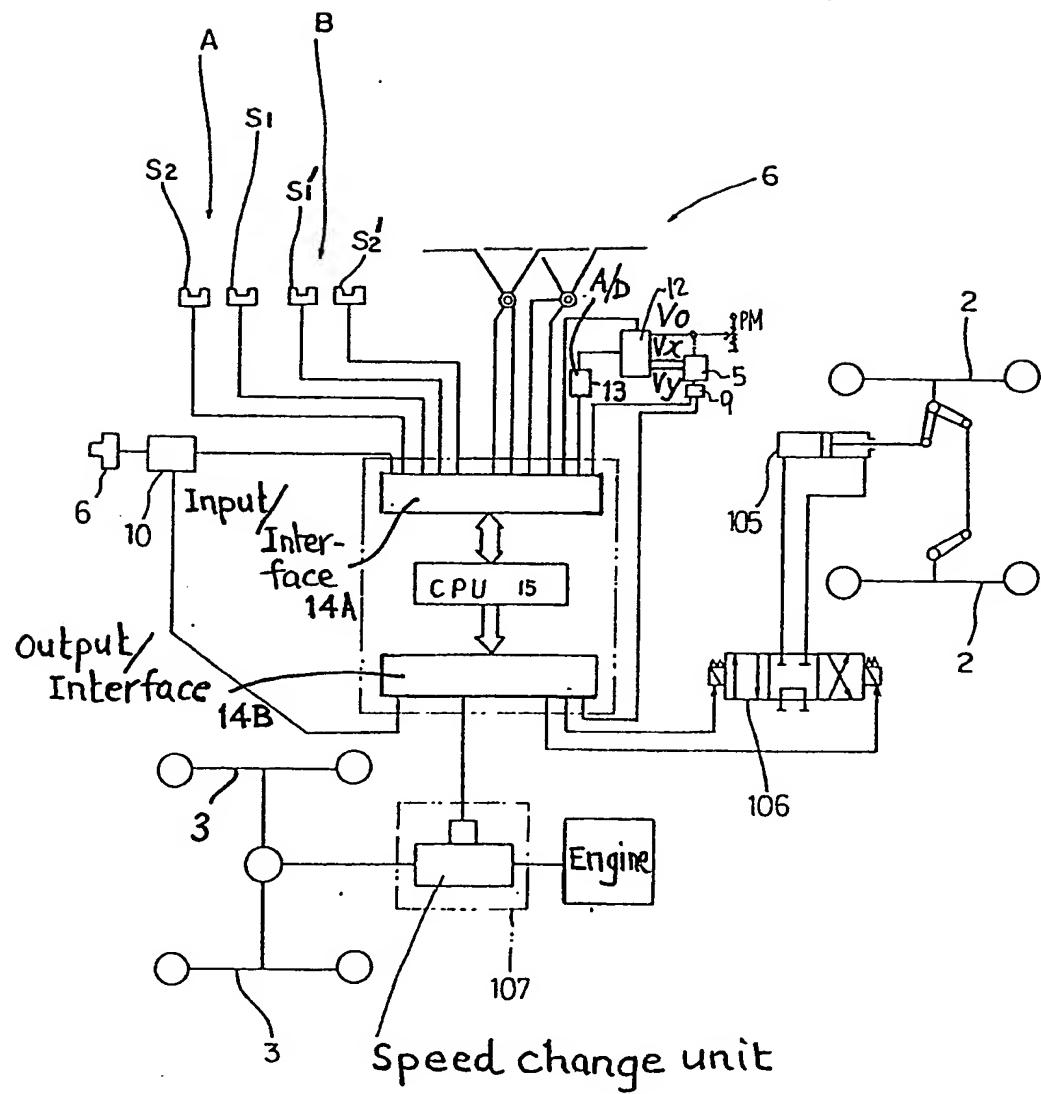


Fig. 5



4/16

2124798

Fig. 6 direction

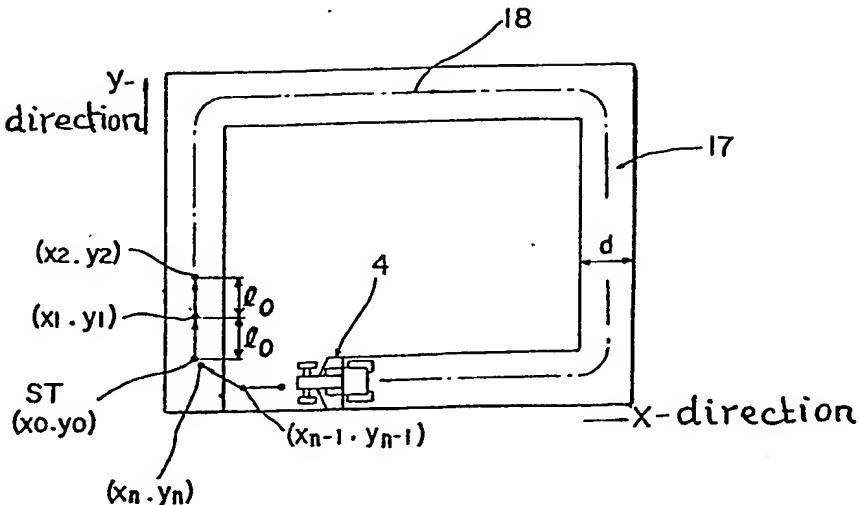


Fig. 7

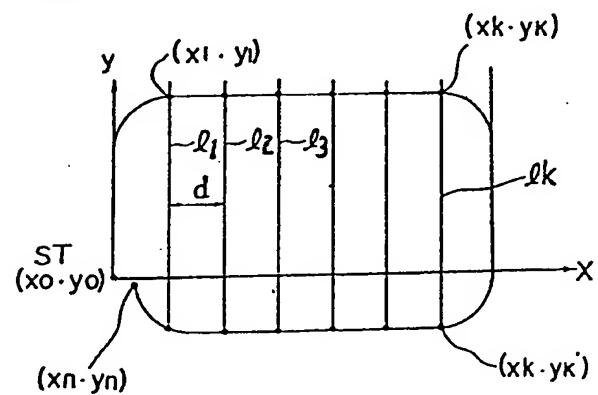
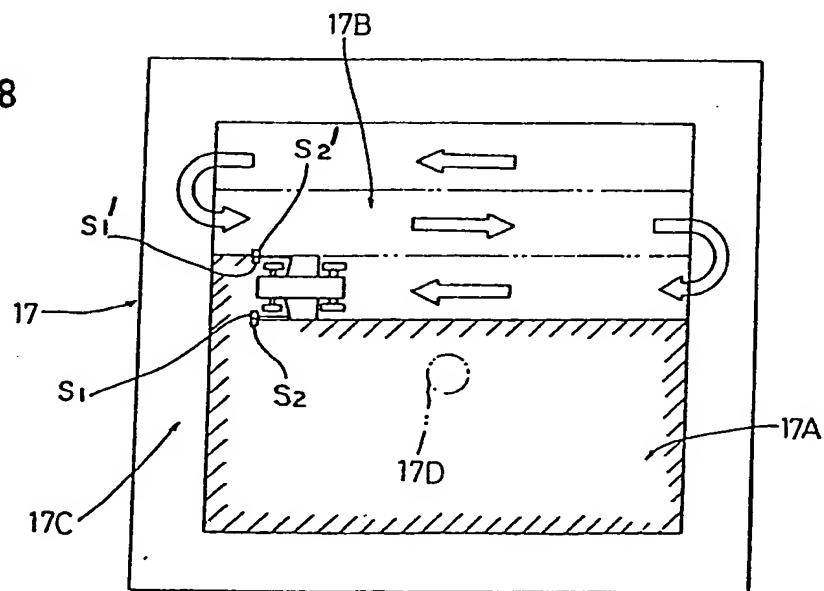


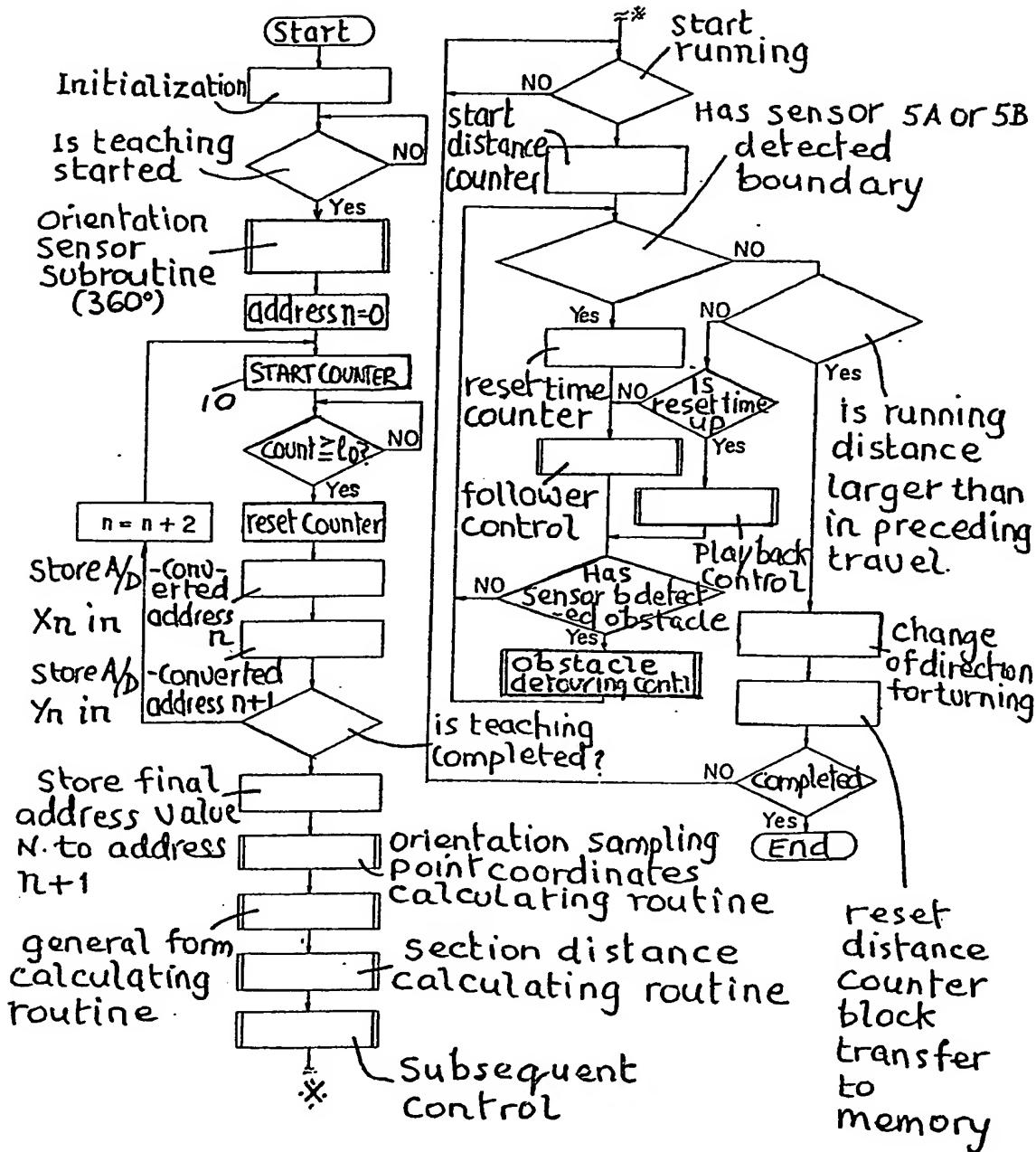
Fig. 8



2124793

5/16

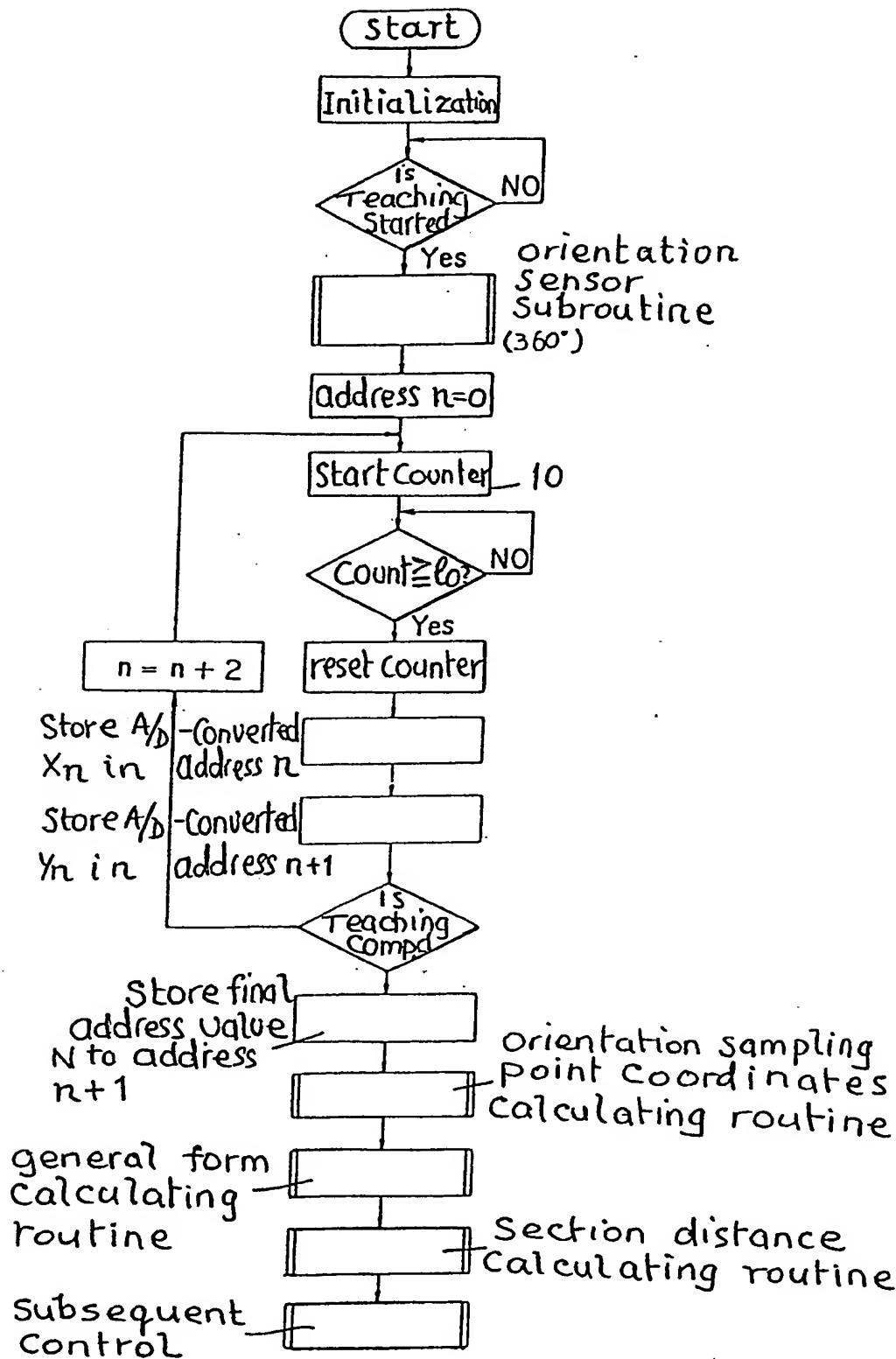
Fig. 9



2124798

6/16

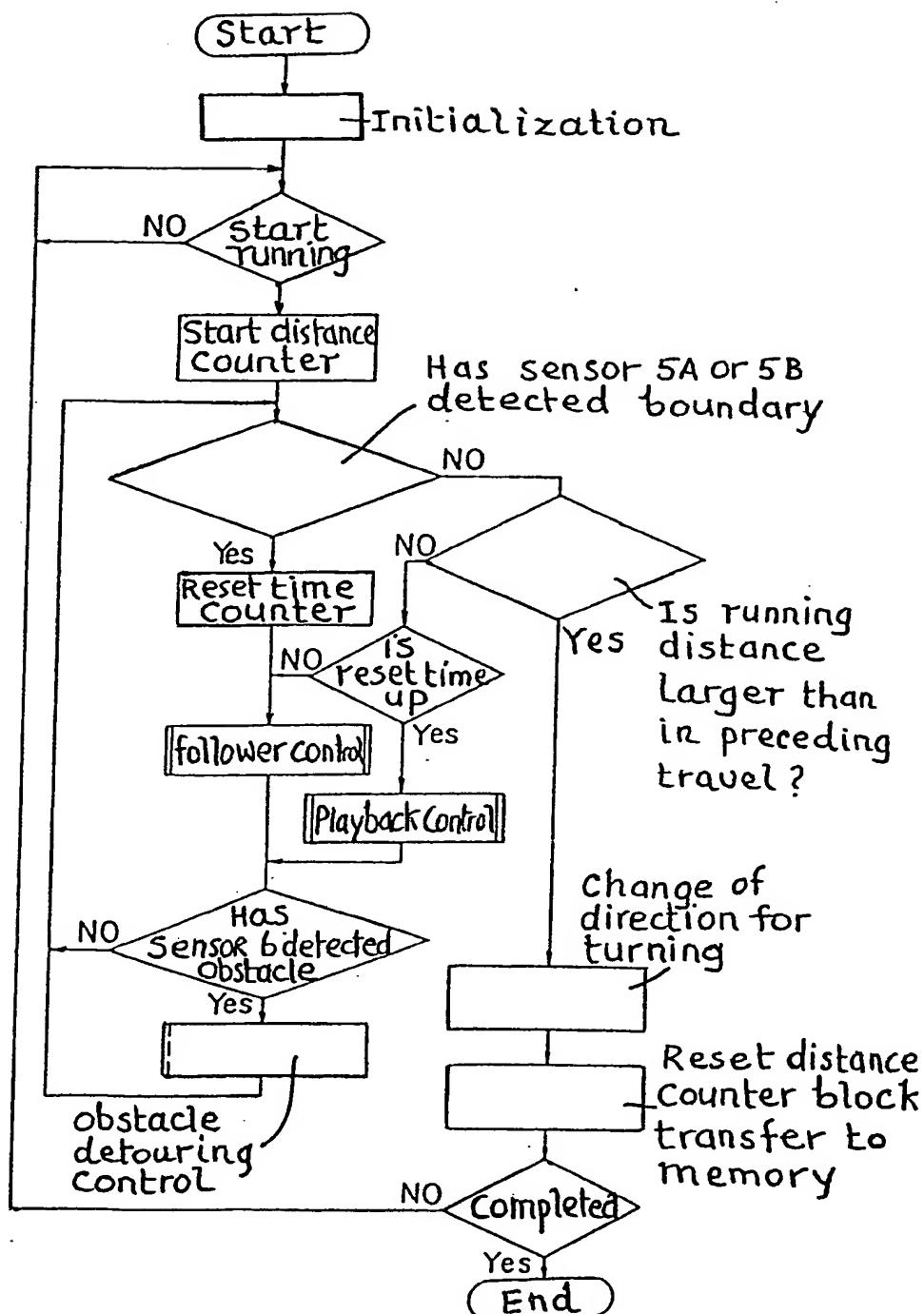
Fig. 10



7/16

2124798

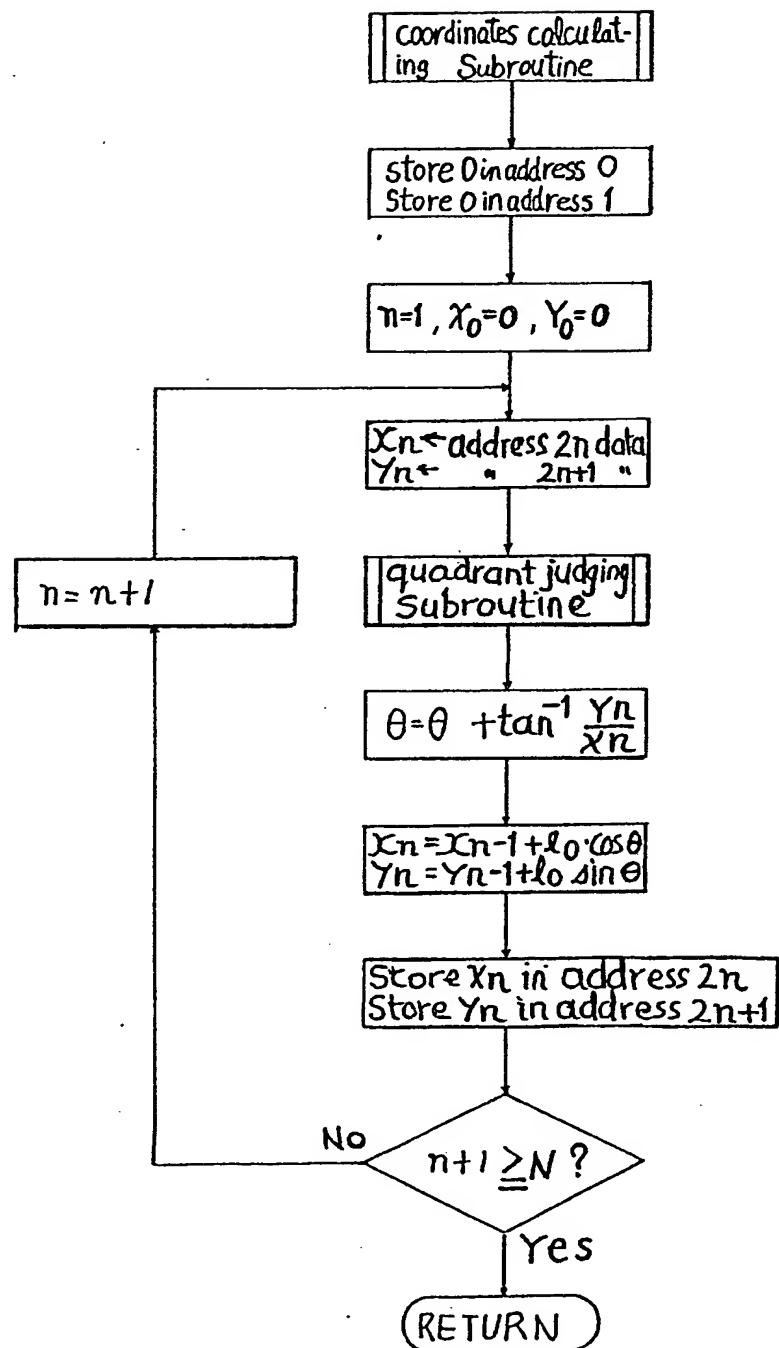
Fig. 11



2124798

8/16

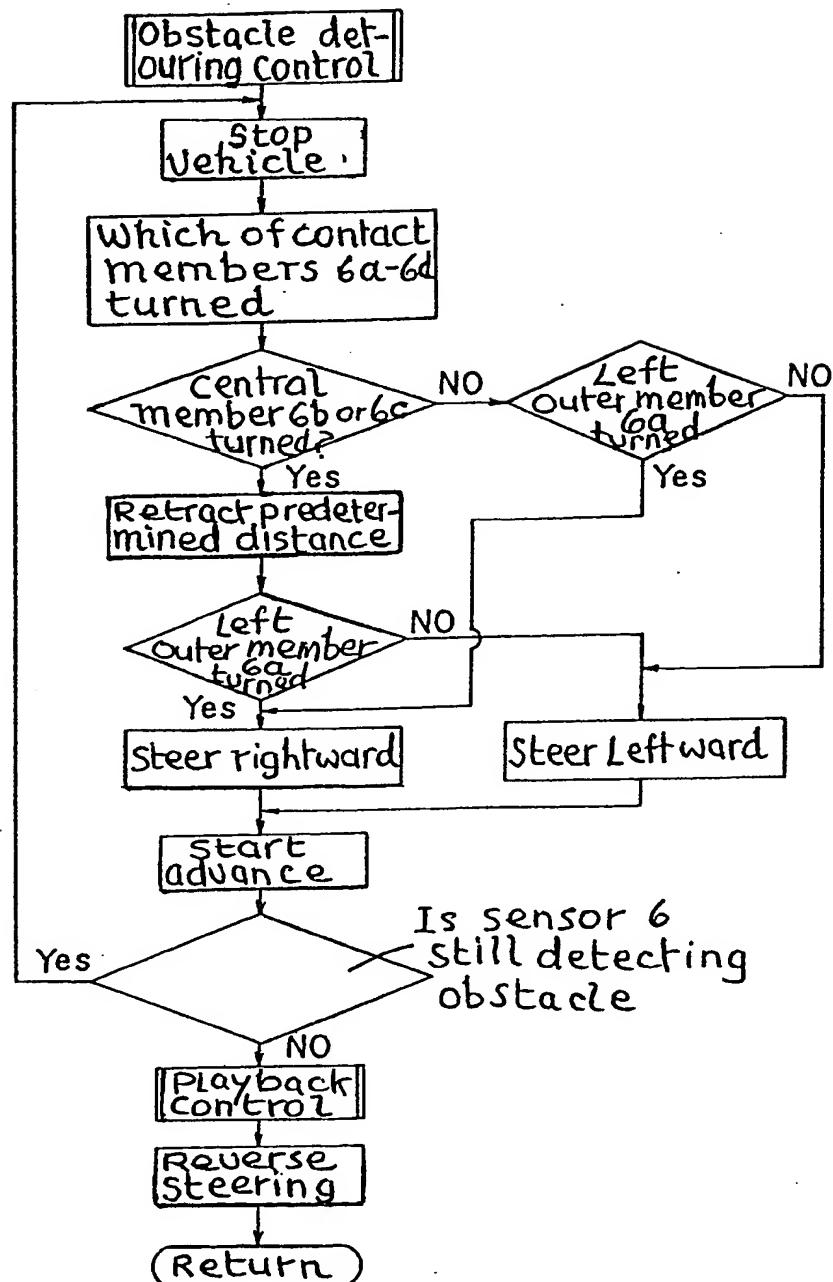
Fig. 12



2124798

9/16

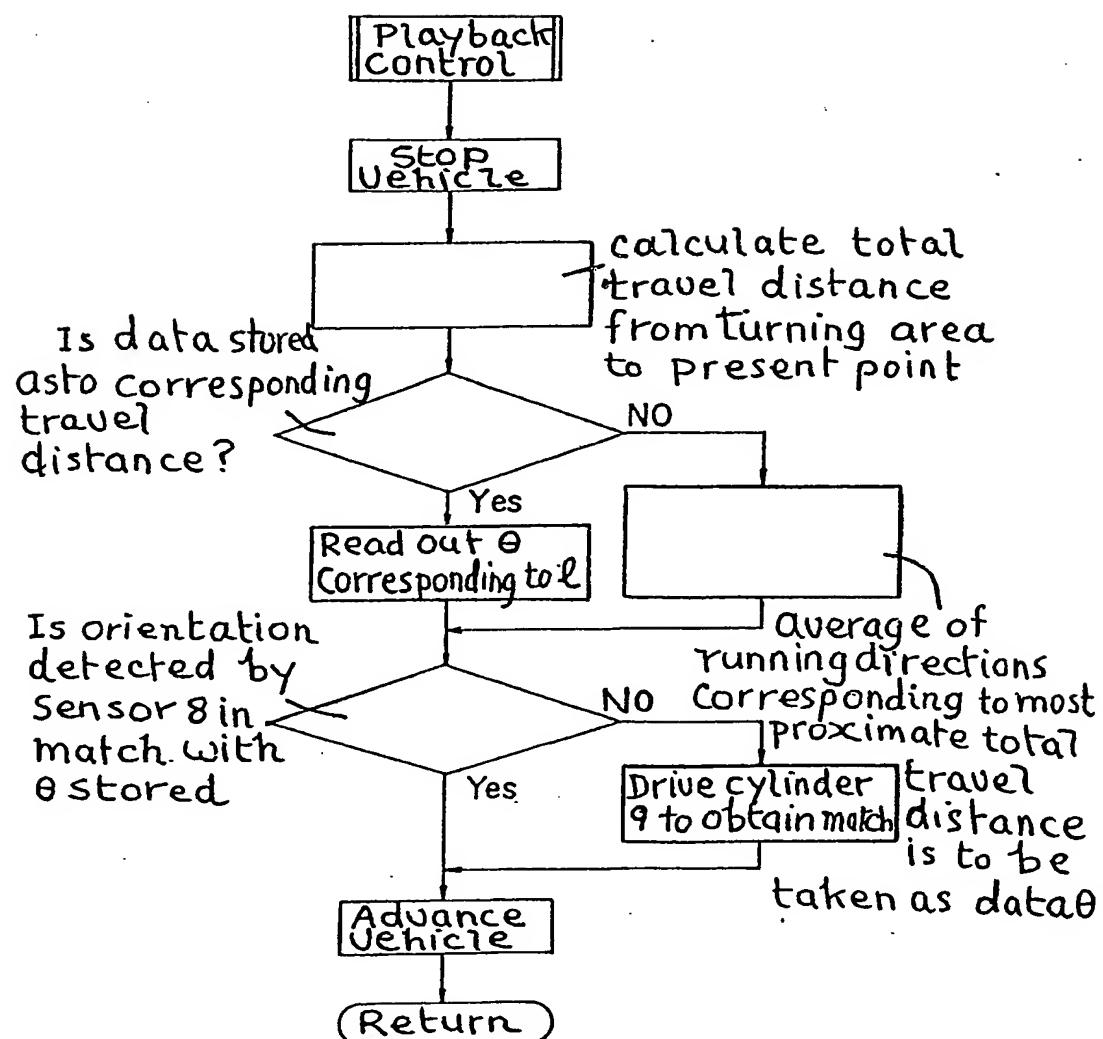
Fig. 13



2124798

10/16

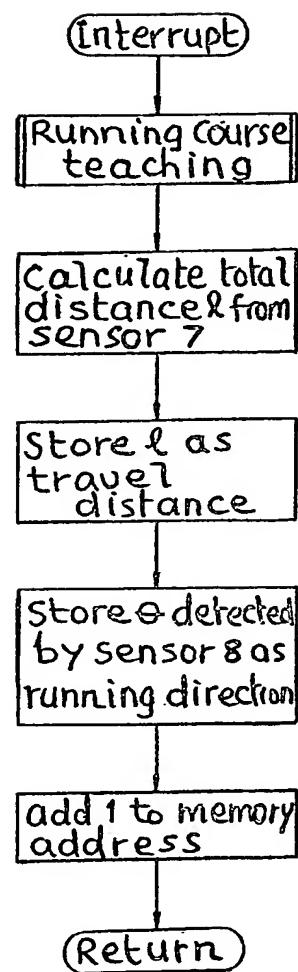
Fig. 14



2124798

11/16

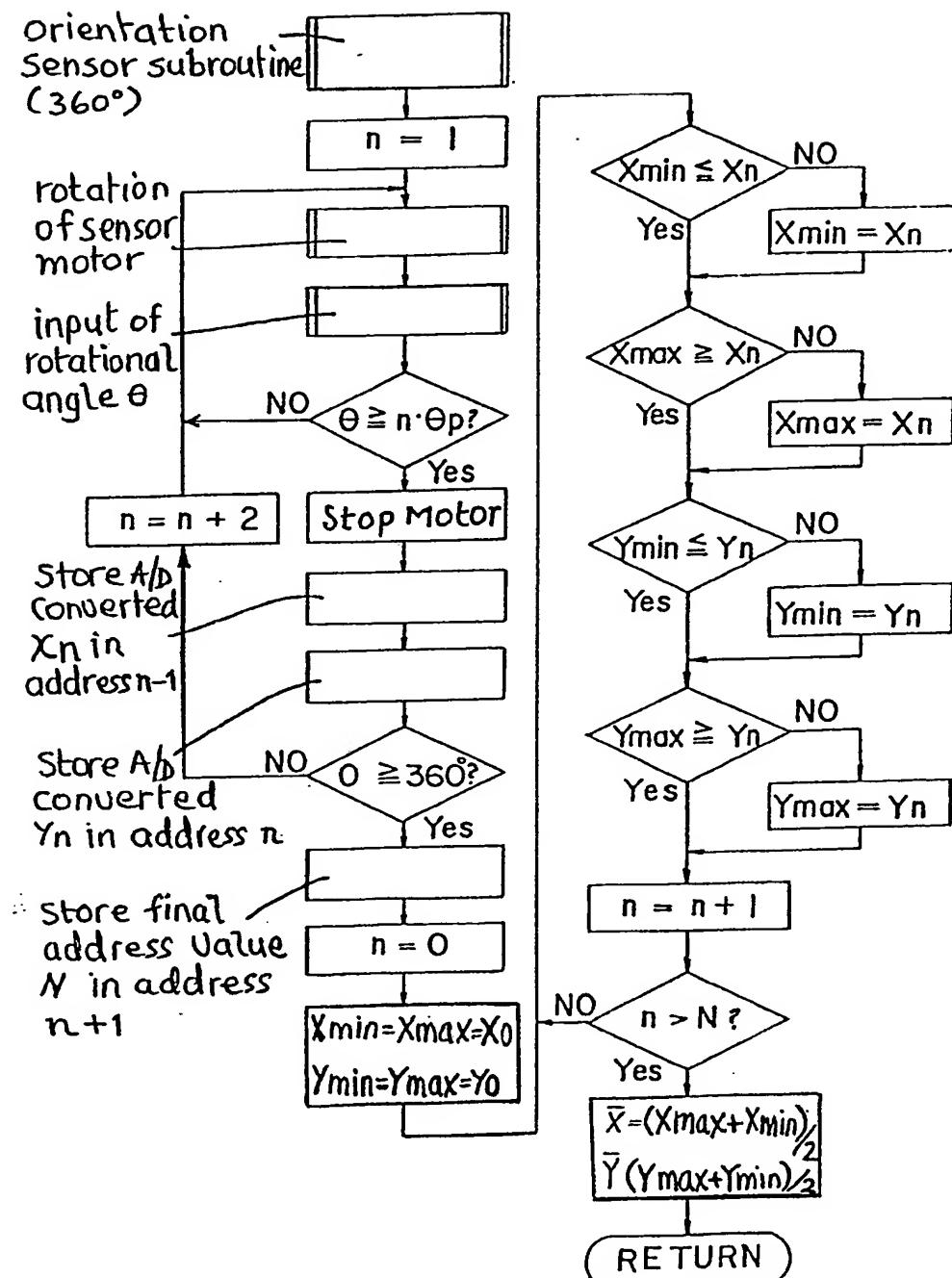
Fig. 15



2124738

12/16

Fig. 16



2124736

13/16

Fig. 17

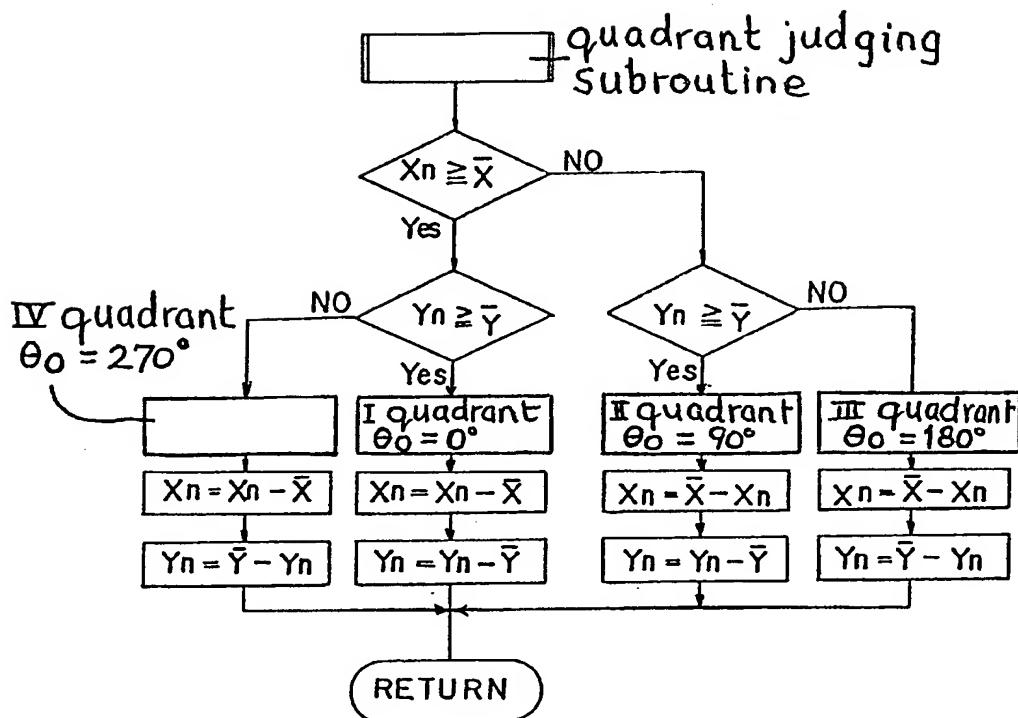
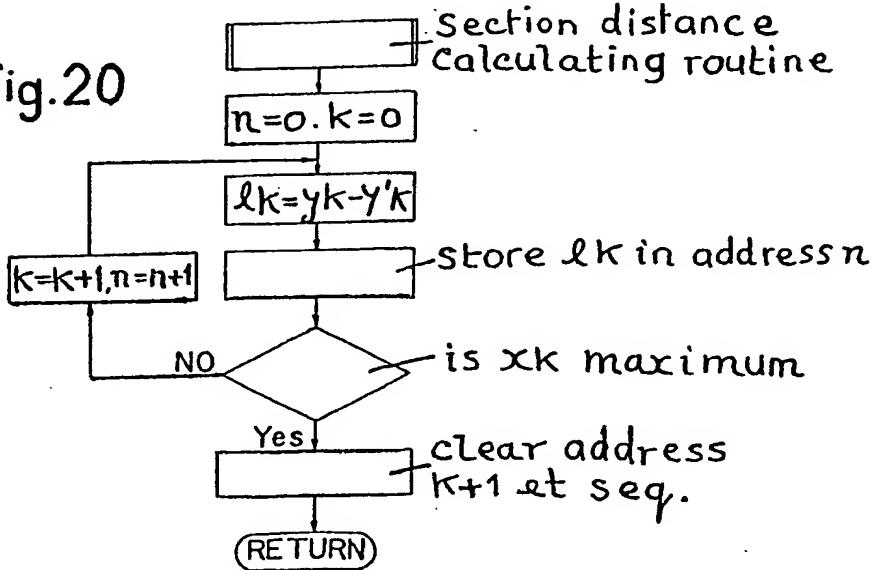
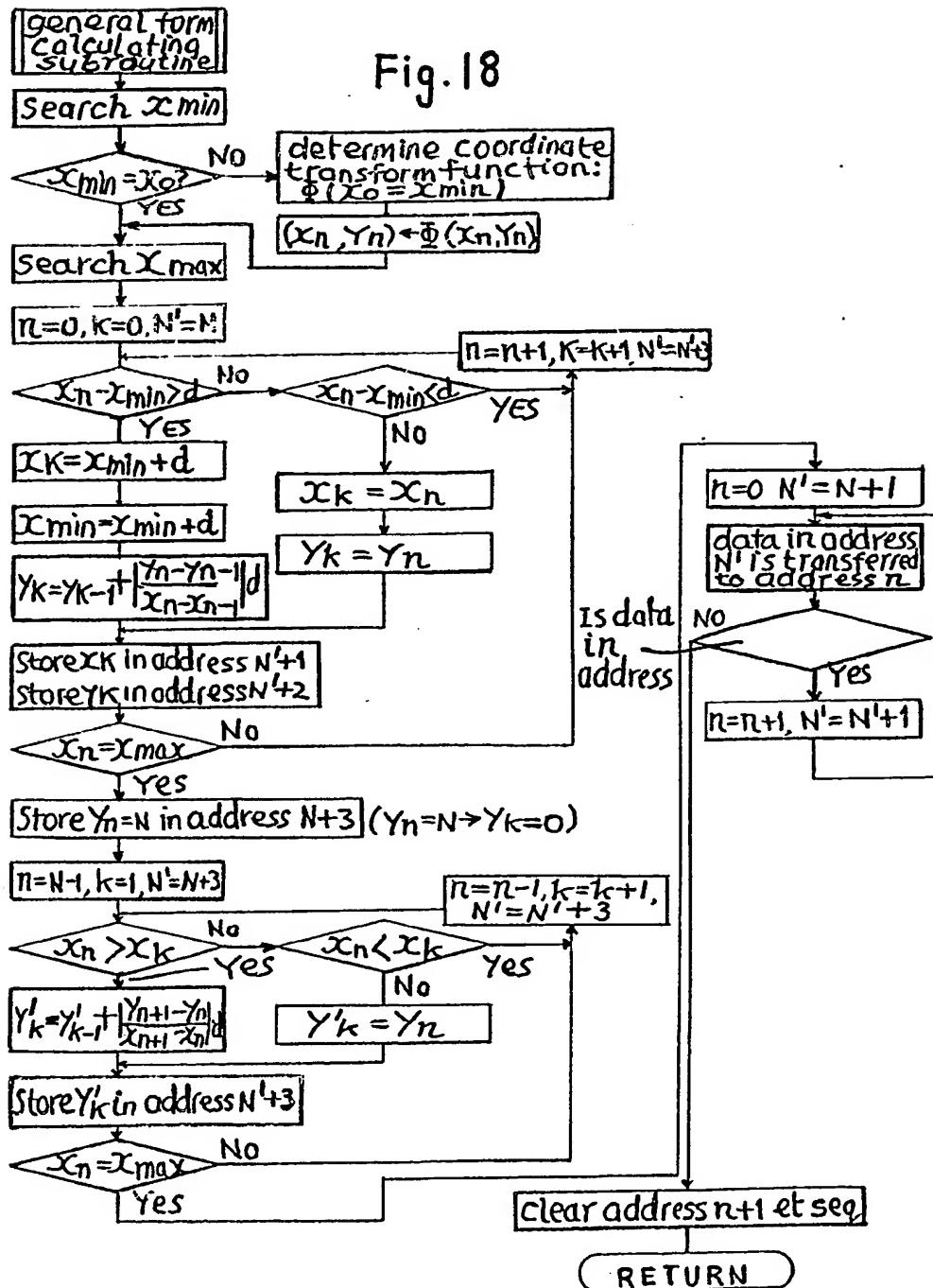


Fig. 20

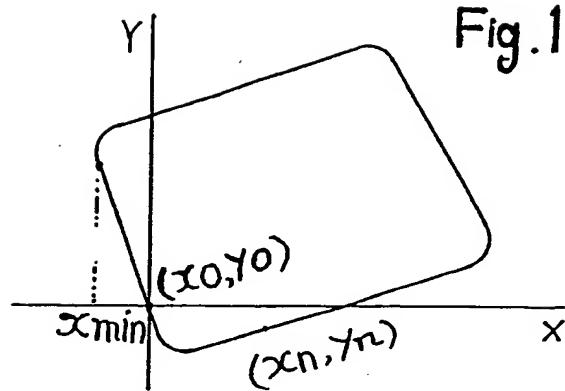




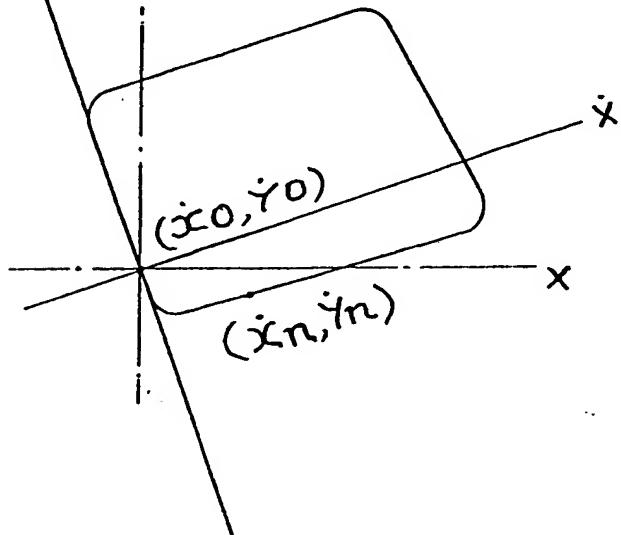
2124798

15/16

Fig. 19



$\Phi | x_0 = x_{min} : \text{coordinate transform function}$   
 $(\dot{x}_n, \dot{y}_n) = \Phi(x_n, y_n)$



2124798

16/16

Fig. 21A

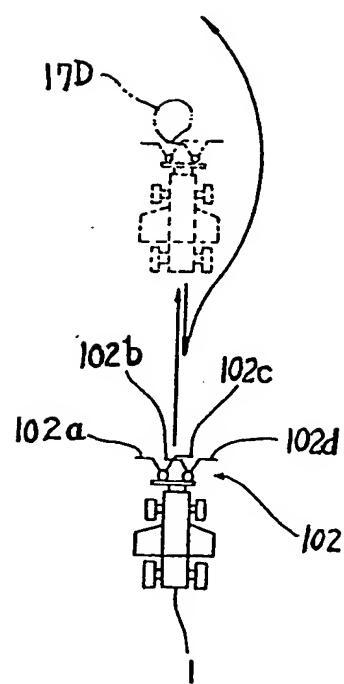
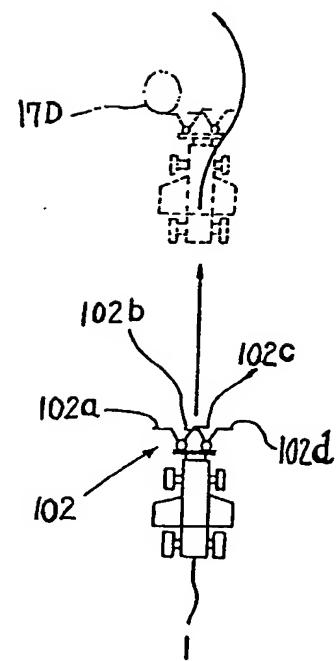


Fig. 21B



**SPECIFICATION****Automatic running work vehicle**

5 The present invention relates to a bulldozer, sprinkling truck, mower or like work vehicle which performs work during its passage while running over a course on a site and which is adapted automatically to run at least part of

10 its course without any driver aboard while carrying out its work.

Such automatic running work vehicles as heretofore known include those for which a teaching/playback control system is used.

15 With such a system, the operator initially manually drives the work vehicle over the entire course to be run automatically subsequently, in order to sample the course as to the running distance, directions, etc. and store 20 the sampling information in a memory. For carrying out the subsequent work, the vehicle is automatically driven along the specified running course in an unmanned state according to the sampling information thus taught as 25 to the running course. Thus, the system involves the necessity of manually driving the work vehicle over the entire running course at least once and is therefore totally useless for the case where the work needs to be performed only once. The system has another 30 drawback in that the memory must store a very large amount of sampling information as to the running course.

An object of the present invention is to 35 provide an automatic running work vehicle which is fully adapted for teaching playback control with the use of a compact device of small memory capacity.

The automatic running work vehicle of the 40 present invention is characterised in that the work vehicle has means for teaching position data at the outer periphery of the entire area of a work site and thereby automatically producing a running course covering the interior 45 thereof, and means for causing the work vehicle to run the running course under steering control.

The above system eliminates the need to 50 store information as to the entire running course and therefore achieves a great saving in the amount of use of the memory required for teaching playback control. Accordingly the work vehicle is fully adapted for teaching playback control for universal use although 55 incorporating a device of much reduced size.

A further object of the present invention is to prevent the work vehicle from turning on the predetermined running course accidentally.

60 To this end, the work vehicle is provided with means for producing a running course which calculates and memorizes the running course distance for every running process on the basis of the width of the work of the 65 running course when the work vehicle goes to

a place and back, and a distance sensor for detecting the distance of travel of the work vehicle and an orientation sensor for detecting the orientation data of the work vehicle, said

70 orientation data being detected and sampled every predetermined distance of travel while teaching the data of the outer periphery of the work site. Thus, while teaching travel of the work vehicle, an orientation data is taught 75 every predetermined distance and the form of the outer periphery of the work site is recognized from the orientation data and then the distance of a running course, i.e. the distance from a turning point to the next turning point 80 of the work vehicle, is newly set for the continuous reciprocal travelling through all the area in the work site, and then the work vehicle is so controlled and steered as to turn with every said distance so that whole of the 85 work site may be worked.

Furthermore, where the work vehicle is provided with follower sensors for detecting the boundary between the worked area and the unworked area and is enabled automatically to 90 travel along the boundary, the following problem occurs, namely when the work vehicle cannot detect the boundary during a running course, automatic travelling is stopped.

It is required under such a situation to 95 enable the work vehicle to travel automatically and continuously in the predetermined direction and to turn surely and automatically only at the correct point where the work vehicle should turn.

100 To solve such a problem it is advantageous to use the travel distance of every running course calculated by the teaching of the position data of the outer periphery of the work site.

105 To fulfill this object, the automatic running work vehicle of the invention is adapted to repeat a running travel reciprocatingly and has follower sensors for detecting the boundary between a worked area and an unworked area

110 for each travel. The work vehicle is characterised in that it is provided with a distance for detecting the running distance of its body, an orientation sensor for detecting the running direction thereof, and means for teaching the

115 running course of one travel by sampling the running direction detected by the orientation sensor every predetermined running distance detected by the distance sensor during the travel, and for steering the work vehicle based

120 on the information of the running course obtained by the teaching of the preceding travel when the follower sensors fail to detect the boundary for a predetermined period of time.

125 Because of the above feature, the work vehicle has the following great advantage. When the follower sensors become no longer able to detect the boundary of the running area during running, the vehicle runs automatically based on the teaching information

130

obtained in the preceding travel, so that the vehicle can be driven automatically with good stability without deviating greatly from the specified running course.

5 The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is an overall side elevation showing an embodiment of automatic running

10 work vehicle provided with a mower;

Figure 2 is an overall plan view of the work vehicle;

Figure 3 is a diagram showing the structure of an orientation sensor;

15 Figure 4 is a fragmentary front view showing a follower sensor;

Figure 5 is a block diagram showing a control system;

Figure 6 is a diagram illustrating the concept of teaching;

20 Figure 7 is a diagram illustrating the concept of conversion of coordinates;

Figure 8 is a diagram showing a specified running course;

25 Figure 9 is a flow chart showing an operation of the control system;

Figure 10 is a flow chart showing another operation of the control system;

Figure 11 is a flow chart showing another

30 operation of the control system;

Figure 12 is a flow chart showing a subroutine for calculation of the coordinates;

Figure 13 is a flow chart showing an obstacle detouring control;

35 Figure 14 is a flow chart showing a playback control;

Figure 15 is a flow chart showing an interruption;

Figure 16 is a flow chart showing a subroutine for an orientation sensor;

40 Figure 17 is a flow chart showing a subroutine for quadrant judging;

Figure 18 is a flow chart showing a subroutine of general form;

45 Figure 19 is a schematic view of a coordinate transform function;

Figure 20 is a flow chart showing a subroutine for calculating each of the course distances; and

50 Figures 21 (A) and (B) are diagrams each showing how to make a detour round an obstacle.

Referring to Figs. 1 and 2, a vehicle body 1 has a mower assembly 4 vertically movably

55 suspended therefrom and positioned between its front and rear wheels 2, 3. The vehicle body 1 further has arranged on opposite sides of its front portion follower sensors 101A, 101B, having the construction to be de-

60 scribed below, for detecting the boundary of a running area, i.e. the boundary between an unmoved area and a mowed area. Thus, the mower is steered along the boundary detected by the follower sensors 101A, 101B so as

65 automatically to run over a specified running

course.

The mower is further provided ahead of its body 1 with an obstacle sensor 102 of the non-contact type for detecting obstacles on

70 the running course.

Additionally, the vehicle body 1 has a fifth wheel serving as a distance sensor 6 for generating a pulse per optional unit of running distance  $l_o$  in order continuously to detect

75 the distance of travel of the vehicle body 1, and an orientation sensor 5 for detecting the running direction of the body 1.

Usually the front wheels 2, 2 are adapted to be steered rightward or leftward by a

80 hydraulic cylinder 105, (Fig. 5) by a predetermined amount based on the result of detection of the boundary by the follower sensors 101A, 101B or on the result of detection of an obstacle by the sensor 102.

85 Each of the follower sensors 101A, 101B comprises a pair of photosensors  $S_1$ ,  $S_2$  and  $S'_1$ ,  $S'_2$ , (Fig. 4) of identical structure disposed ahead of each side of the mower assembly 4.

90 Fig. 4 shows the structure of the photosensors  $S_1$ ,  $S_2$  and  $S'_1$ ,  $S'_2$ . A sensor mount frame 104 attached to the mower assembly 4 is fixed provided with substantially U-shaped sensor frames 103, 103 arranged side by

95 side laterally of the vehicle body 1. Each sensor frame 103 has a light-emitting element  $P_1$  and photocell  $P_2$  on the opposed inner sides thereof for detecting the presence or absence of grass to be brought into the space

100 therebetween with the travel of the vehicle body 1 in order to detect the boundary between the mowed area and the unmoved area.

It can be seen from Fig. 8 that when the

105 follower sensor 101A composed of the photosensors  $S_1$ ,  $S_2$  or the follower sensor 101B composed of the photosensor  $S'_1$ ,  $S'_2$  is in the unmoved area 17A, the vehicle is so steered for running that the outer photosensor  $S_2$  or

110  $S'_2$  only of the other follower sensor is positioned in the mowed area 17B. Upon reaching a turning area 17C around the mowing area 17, the vehicle is turned toward the follower sensor which has been in the un-

115 mowed area 17A. The turning area 17C consists of an area mowed in advance by non-automatically driving the mower. Upon the arrival of the vehicle at the turning area 17C, all the four photosensors  $S_1$ ,  $S_2$  and  $S'_1$ ,  $S'_2$

120 constituting the follower sensors 101A, 101B detect the mowed area, indicating this arrival.

The follower sensors 101A, 101B are not limited to those comprising photosensors  $S_1$ ,  $S_2$  and  $S'_1$ ,  $S'_2$  but can be composed of other

125 sensors of the non-contact, contact or any other type.

The obstacle sensor 102 comprises four contact members 102a, 102b, 102c, 102d arranged ahead of the vehicle body 1 and,

130 spaced approximately over the entire width of

the body 1, usually biased forward and each individually turnable rearward by contact with an obstacle, and switches  $S_3, \dots$  provided at the base ends 102e, ... thereof for detecting 5 the turn of the contact members 102a, 102b, 102c, 102d, respectively.

The position where an obstacle comes into contact with the sensor 102 is detectable in 10 four divided ranges corresponding to the operative positions of the switches  $S_3, \dots$

As seen in Fig. 3, the orientation sensor 5 comprises a toroidal core 7 having an exciting coil  $C_0$  wound thereon, and output coils  $C_x, C_y$  diametrically wound on the coil  $C_0$  and intersecting each other at right angles. When the toroidal core 7 is subjected to an external magnetic field (geomagnetism) with a.c. current passed through the exciting coil  $C_0$ , the output coils  $C_x, C_y$  generate a.c. signal voltages in proportion to the external magnetic field. The a.c. signal voltages generated in the output coils  $C_x, C_y$  are amplified to a predetermined level and then converted to d.c. voltages  $V_x, V_y$ , the ratio of which indicates 25 an orientation.

The toroidal core 7 constituting the orientation sensor 5 is provided with rotating means A rotatably through 360° about a vertical axis P for correcting the difference in the magnetic 30 sensitivity of the output coils  $C_x, C_y$  in different orientations and enabling these coils to detect the running direction of the vehicle body 1 relative to a specified orientation.

The rotating means A comprises a nonmagnetic bracket 8 having the toroidal core 7 fixed thereto, and a motor 9 for rotating the bracket 8 clockwise or counter-clockwise. A potentiometer PM is provided on the axis P for detecting the angle  $\theta$  of rotation of the 40 sensor.

The distance sensor 6 generates a pulse per unit distance of travel of the vehicle body 1. A counter 10 counts up a specified number of pulses to detect a predetermined distance of 45 travel,  $l_0$ .

Next, a control device 11 will be described which serves as a general form of teaching device for calculating the general form of a work site from sampling information. The information is obtained by sampling a running 50 course around the work site based on the detection signals from the orientation sensor 5 and the distance sensor 6 of the foregoing construction.

55 With reference to Fig. 5, the d.c. voltages  $V_x, V_y$  delivered from the orientation sensor 5 and serving as orientation detecting signals and the voltage  $V_\theta$  given by the potentiometer PM and representing the angle of rotation of the sensor 5 are fed through a signal detector 12 to an A/D converter 13, in which the voltages are converted to digital signals. The signals are fed to an arithmetic unit 15 of the control device 11 via an input-output interface 60 14. Every time the specified number of pulses

(corresponding to the predetermined travel distance  $l_0$ ) from the distance sensor 6 have been counted up by the counter 10, the voltages  $V_x, V_y$  representing the orientation 70 data detected by the orientation sensor 5 are sampled and stored in a predetermined address area of CPU 15.

In order to correct, with respect to over orientation, the sensitivity with which the 75 geomagnetism is detected by the orientation sensor 5, prior to the orientation sampling to be carried out every predetermined travel distance  $l_0$  and also to recognize detected absolute orientations in terms of changes in the 80 running direction of the vehicle body 1 relative to the specified direction of the work site during travelling for teaching, average detection voltages  $\bar{X}, \bar{Y}$  with respect to a reference orientation are calculated prior to the teaching 85 of the outer periphery of the work site, by rotating the orientation sensor 5 through 360° with the vehicle body 1 at a halt and sampling the detection voltages  $V_x, V_y$  every specified angle  $\theta_p$  (Fig. 16).

90 The control system will now be described for automatically controlling the running of the mower, based on the detection signals from the sensors 5, 6, 101A, 101B and 102 of the above described construction.

95 With reference to Fig. 5, the control system comprises CPU 15 the main portion of which is a microcomputer. The signals from the follower sensors 101A, 101B the obstacle sensor 102, the distance sensor 6 and the 100 orientation sensor 5 are fed to CPU 15 via an input interface 14A. Based on the signals from these sensors, CPU 15 performs an arithmetic operation and gives the result, i.e., control signals, to an output interface 14B to 105 cause an electromagnetic valve 106 to drive the hydraulic cylinder 105, which is an actuator, thus operating the front wheels 2, 2 and a speed change unit 107.

First, the operator manually drives the work 110 vehicle so as to make a round of the outer periphery 18 of the work site 17, (Fig. 6), so that lawn in the area of the cutting width  $d$  of the mowing assembly 4 may be cut, or drives the work vehicle to make a further round so 115 as to cut lawn in the area of the double width (2d) of the cutting width  $d$ . During the running, the detection voltages  $V_x, V_y$  from the orientation sensor 5 are sampled every predetermined travel distance  $l_0$  from the start point 120 ST to obtain orientation data  $X_n, Y_n$  as converted to displacement values relative to the reference orientation voltages,  $\bar{X}, \bar{Y}$ , and the data is stored in a predetermined address area of CPU 15.

125 After the teaching of the work site outer periphery 18, the vehicle body 1 is stopped temporarily at the start point ST or in the vicinity thereof, and the coordinates  $(X_n, Y_n)$  of the sampling points of the outer periphery 18 130 on the coordinate system having the start

point ST as origin are calculated by the following procedure, (Fig. 6, Fig. 7).

Stated more specifically, the items of orientation data  $X_n$ ,  $Y_n$  are compared with the reference orientation voltages  $X$ ,  $Y$  respectively to judge the quadrant of the running direction and calculate the orientation  $\theta$  of the running direction with respect to the reference orientation (Fig. 17). The coordinates  $(x_n, y_n)$  of each of the sampling points are calculated from the orientation  $\theta$ , the predetermined travel distance  $l_o$  and the coordinates  $(x_{n-1}, y_{n-1})$  of the preceding sampling point and are stored in the same address area of CPU 15 as the orientation data  $x_n$ ,  $y_n$ , whereby the orientation data  $x_n$ ,  $y_n$  obtained for the outer peripheral teaching is replaced by the coordinate data  $x_n$ ,  $y_n$  of the work site outer periphery (Fig. 12). The coordinates of the start point ST are preset as coordinates (0, 0) and the coordinates  $(x_n, y_n)$  of the other sampling points are calculated in terms of distances from the reference coordinates (0, 0) in x-direction and y-direction.

25 The sampling information of the teaching phase converted to the coordinate system with respect to the start point ST, as origin, by the above procedure is further converted by the following procedure to a coordinate system utilizing the cutting width  $d$  of the mowing assembly 4 as a unit for the coordinate system.

First, referring to Fig. 18, since it is desirable that the x-axis direction on the coordinate system is accorded with the travelling direction of the work vehicle at the starting point for the teaching operation, or in other words the minimum value  $x_{\min}$  of x-coordinate at the sampling point is  $x_o$ , when in the relation 35 of  $x_{\min} = x_o$ , the coordinate system is rotated about the origin thereof in order to obtain the relation of  $x_{\min} = x_o$ . As the result, the coordinates  $(x_n, y_n)$ , become new coordinates  $(\dot{x}_n, \dot{y}_n) = \Phi l x_o = x_{\min} (x_n, y_n)$  40 where the coordinate transform function is  $\Phi l x_o = x_{\min} l$ . When the coordinates  $\dot{x}_n, \dot{y}_n$ , are replaced by the coordinates  $x_n, y_n$ ;  $x_n, y_n$  become the coordinates on the coordinate system which defines  $x_o = x_{\min}$ , as shown in 50 Fig. 19.

Thereafter, the maximum value  $X_{\max}$  and minimum value  $X_{\min}$  on the x-coordinates of the coordinates  $(x_n, y_n)$  of the sampling points are calculated again. Based on the minimum 55 value  $X_{\min}$ , the coordinates  $(x_k, y_k)$ ,  $(x_k, y_k')$  corresponding to X values  $x_k$ ;  $x_k = X_{\min} + k \cdot d$ , increased by a distance of the cutting width(s)  $d$  from the minimum  $x_{\min}$  are calculated by the interpolation method, and the resulting 60 data is totally substituted for the data in the address area of the memory 16 in which the sampling point coordinates  $x_n, y_n$  are stored. Thus the general form of the work site is calculated and stored in terms of the coordinates  $(x_k, y_k)$ ,  $(x_k, y_k')$  which are directly usable 65

for mowing.

The data of coordinates  $(x_k, y_k)$ ,  $(x_k, y_k')$  thus calculated can be stored in a smaller memory area than the sampling information stored for 70 the outer periphery teaching, so that the amount of the memory eventually used can be smaller.

Based on the coordinates  $(x_k, y_k)$ ,  $(x_k, y_k')$  corresponding to every cutting width  $d$ , the 75 distance  $l_1, \dots, l_k$  for each straight section of the running course is calculated from the coordinates  $(x_k, y_k)$ ,  $(x_k, y_k')$ , i.e.  $l_k = y_k - y_k'$  (Fig. 20). Thus it is easy to calculate the 80 information, such as the running course which is required, for example, for automatic steering in the mowing operation to be conducted after the teaching of the general form.

Thereafter, on the basis of the results of detecting the boundary by the follower sensors 85 101A, 101B, the front wheels 2, 2 are steered and the work vehicle starts to run under the follower control so as to run along the boundary between the unmowed area and the mowed area from the turning area 17C in 90 the vicinity of the starting point ST and then automatically travels in the predetermined direction.

If while travelling under follower control, there is located an obstacle 17D on the running course between the turning area 17C and when the obstacle sensor 102 detects the obstacle 17D, an obstacle deviation or detouring control is carried out in preference to the follower control which is based on the detecting 100 signals from the follower sensors 101A, 101B.

The obstacle detouring control will be described below (Fig. 13).

When one of the switches  $S_3, \dots$  of the 105 obstacle sensor 102 is turned on upon detecting an obstacle, the follower control is interrupted, and the speed change unit 16 is operated to temporarily stop the vehicle body 1. The switch  $S_3$  actuated is identified in order 110 to determine which of the contact members 102a, 102b, 102c, 102d has come into contact with the obstacle. If the contact member 102b or 102c in the center is in contact therewith, the vehicle body 1 is retracted a 115 predetermined distance and then advanced and steered toward a given direction as shown in Fig. 21A. When the vehicle body is to be thus retracted temporarily, the data indicating the particular contact member in contact with 120 the obstacle is temporarily stored in the memory to determine the detouring direction, and the vehicle is thereafter steered in the detouring direction immediately before it is advanced. The detouring direction determined is 125 toward one side opposite the particular contact member concerned.

If only one of the outer members 102a, 102d has come into contact with the obstacle, the vehicle is advanced as it is steered 130 toward a direction opposite to that member,

as shown in Fig. 21B.

After the vehicle has been brought into the advance travel for detouring around the obstacle, the vehicle is steered according to the

- 5 running course information obtained by teaching in the course of the preceding travel as will be described later, to automatically return to the running course before the detouring.
- 10 The control by the follower sensors 101A, 101B is thereafter resumed automatically to drive the vehicle in the specified direction.

Further, the work vehicle is provided with a teaching function whereby the information as to each of the course runs by the vehicle

- 15 under the follower control as well as under the obstacle detouring control will be sampled and stored for teaching in the following manner.

There will now be described hereunder the 20 manner of the course teaching.

The running course sampling is an interrupt process (Fig. 15) which is initiated most preferentially in response to a pulse count signal emitted by the distance sensor 6 every predetermined distance of travel,  $l_0$ , which is predetermined as the sampling interval for the running course.

With reference to Fig. 8, the overall control program is so designed as to sample and 30 store the running course information for every travel which is initiated upon the detection of the unmowed area 17A by one of the photo-sensors  $S_1, S_2, S'_1, S'_2$  constituting the follower sensors 101A, 101B with the advance 35 of the vehicle body 1 from the turning area 17C into the unmowed area 17A shown in Fig. 8 and which is completed when the mowed turning area 17C is detected by all the photosensors  $S_1, S_2, S'_1, S'_2$ .

40 More specifically stated, when the vehicle body 1 starts running under the follower control from one end of the turning area 17C around the unmowed area 17A, a counter simultaneously starts counting up the pulse signals from the distance sensor 6, and every time the vehicle body 1 has run the predetermined distance  $l_0$ , the running direction  $\theta$  detected by the orientation sensor 5 at that time and the total distance  $l$  of travel after the 45 start of counting are stored in a specified memory area within the control unit 15' as teaching data obtained by sampling the running course. The running course is sampled and stored also when the vehicle is under the 50 obstacle detouring control by similarly storing the steering angle, i.e., the running direction  $\theta$ , every time the vehicle has covered the travel distance  $l_0$ .

As seen in Fig. 8, the running direction of 60 the vehicle body reciprocatingly reverses from one travel to the next travel. In a subsequent travel, therefore, the running course information obtained by the teaching of the preceding travel is read out in an order reverse to the 65 storing order. Thus the data is retrieved from

the memory in response to the signals from the distance sensor 6 by reversely referring to the address concerned.

As described above, while the work vehicle 70 travels under the follower control by teaching each of the running courses, when one of the follower sensors 101A, 101B does not detect the unmowed area or cannot detect the boundary. After a predetermined period of 75 time has passed, the playback control takes place to cause the work vehicle automatically to run in the predetermined direction by advancing the work vehicle after forcibly steering the work vehicle to face the direction 80 turned 180° from the direction  $\theta$  at the present point on the path of the running course between the turning area 17C.

Where there is a bare or turfless spot on the running course and when the follower sensors 85 101A, 101B detect no unmowed area 17A, namely the same circumstances as that in which the work vehicle should be turned, comparison is made between the actual distance  $l$  from the turning area to the present 90 point and one process of the running course distance  $l_1, l_2, \dots, l_k$ , previously calculated and memorized during the teaching of the outline of the work site, and as the result, when the actual distance  $l$  is smaller than the preset 95 running course distance  $l_1, l_2, \dots, l_k$ , including the range of a detection error, the work vehicle is advanced automatically and forcibly under the steering control in the predetermined direction with reference to the running 100 direction data  $[l, \theta]$  obtained in the preceding process as in the manner explained hereinbefore.

In this case, the arrangement may be modified so as not to effect a steering control on 105 the basis of the data obtained by the teaching in the preceding process, but to simplify so as to merely advance the work vehicle by preventing same from running under the follower control until the unmowed area 17A is detected by one or both of the follower sensors 110 101A, 101B.

Further, only when both the follower sensors 101A, 101B detect the mowed area, i.e. the turning area 17C and the actual running 115 distance  $l$  in one process of travel is accorded with the preset running distance  $l_1$  ( $l = l_1$  in first process;  $l = l_2$ , second process;  $l = l_k$   $k$ -th process), the work vehicle is automatically steered to the utmost in the turning area 17C 120 and then the next process of travel starts under the follower control.

Also, when the obstacle detouring control is carried out during automatic running under the follower control, the running course after 125 detouring the obstacle 17D is revised or correct and then the work vehicle is automatically steered by means of the playback control to take the predetermined running course.

Thus, the running course data  $[l, \theta]$  taught 130 in each of the processes of the running

course, are replaced by the running course data  $[l, \theta]$  newly taught in the present process when the work vehicle 1 turns in the turning area 17C, and then the vehicle runs along the 5 boundary under the follower control.

Fig. 9 is a flow chart showing the function of the above mentioned CPU 15.

The orientation sensor in the above described embodiment may be replaced by a 10 potentiometer which is mounted on the axles of the front wheels 2, 2 to provide means for detecting a steering angle, or it may utilize the distance sensor 6 to detect the running direction of the fifth wheel instead of detecting the 15 steering angle of the front wheels 2, 2.

As described above, in the work vehicle according to this embodiment, each of the processes of the running course, which is utilized for automatic steering control of the 20 work vehicle, is calculated and memorized by teaching position data on the outer periphery of all the work site. Then, in the actual running after completion of the initial teaching, only the position data of one process of 25 travel through which the work vehicle has just passed, may be memorized and utilized for the playback control (Fig. 14) when the follower control cannot take place. Thus, there is no need to memorize all of the running course 30 data for surely and correctly controlling the work vehicle.

Moreover, in this embodiment, in addition to the construction which makes teaching of the outer periphery of the work site for calculating each of the processes of travel of the running course, there is provided the construction for teaching each of the processes of travel while actual travelling.

However, where the work vehicle does not 40 slip or get out of the predetermined direction due to the good condition of the work site, it is possible to control the work vehicle by utilizing only the distance data of each of the processes of the running course without the 45 follower control.

A simplified embodiment for working the above control system will now be described.

A work vehicle body 1 has a mower assembly 4 vertically movably suspended therefrom and positioned between the front and rear wheels 2 and 3. The vehicle body 1 further has an orientation sensor 5 on a front portion thereof for sensing the geomagnetism and thereby detecting the running direction of 50 the body 1, and a fifth wheel connected to its rear end and serving as a distance sensor 6 for continuously detecting the distance of travel of the vehicle body 1.

After completion of initial teaching of the 60 outer line of the work site, the work vehicle starts mowing the turf. As the work vehicle actually runs through the preset distance of a process of the travelling course, the work vehicle turns and continues the mowing work.

65 A flow chart for showing the function of

CPU 15, is Fig. 10.

As will be seen from the flow chart, the work vehicle which may automatically travel without the follower control, may be constructed using a small capacity of memory and a simple program.

Furthermore, it is possible to provide such a work vehicle which does not set the running distance by the initial teaching, but carries out 75 teaching of position data of each of the processes of the running course every time while actual travelling and provides not only the follower control, but also means for steering the work vehicle to run on the basis of the 80 running course data taught in the preceding course in the event that the follower sensors detect no boundary for a predetermined period of time.

When the follower sensors are no longer 85 able to detect the boundary of the running area during running, the vehicle runs automatically based on the information of teaching obtained in the preceding travel, so that the vehicle can be driven automatically with good 90 stability without deviating greatly from the specified running course.

This type of work vehicle will now be described.

As in the first embodiment, the work 95 vehicle mowing the turf is provided with an orientation sensor 5, a distance sensor 6, follower sensors 101A, 101B, an obstacle detecting sensor 6 and so forth. A control system having a microcomputer as an essential 100 element thereof is substantially the same as in the first embodiment, but there is a different flow in the control as shown in Fig. 11.

More specifically stated, when the vehicle 105 body 1 starts running under follower control from one end of the turning area 17C around the unmowed area 17A, a counter simultaneously starts counting up the pulse signals from the distance sensor 6, and every time 110 the vehicle body 1 has run the predetermined distance  $l_0$ , the running direction  $\theta$  detected by the orientation sensor 5 at that time and the total distance  $l$  of travel after the start of counting are stored in a specified memory 115 area within the control unit 15' as teaching data obtained by sampling the running course. The running course is sampled and stored also when the vehicle is under the obstacle detouring control by similarly storing 120 the steering angle, i.e., the running direction  $\theta$ , every time the vehicle has covered the travel distance  $l_0$ .

As seen in Fig. 8, the running direction of the vehicle body repeats a travel which is 125 reciprocatingly reverse from travel to travel. In the subsequent travel, therefore, the running course information obtained by the teaching of the preceding travel is read out in an order reverse to the storing order. Thus, the data is retrieved from the memory in response to the

signals from the distance sensor by reversely referring to the address concerned.

Thus, it is similar to the first embodiment that the playback control or the obstacle detouring control is carried out while travelling.

When the vehicle body changes its direction at the turning area 12D, the running course information  $I, \theta$  newly taught in the present travel is block-transferred to the memory area 10 storing the information of the preceding travel. The vehicle therefore runs along the boundary of the running area under follower control with the contents of its memory renewed from travel to travel.

15 In this way, the vehicle is automatically taught the running course information as to one travel only, so that a memory of greatly reduced capacity is usable for storing the running course information  $I, \theta$ , while there is 20 no need for the operator to teach the running course.

Although the orientation sensor 5 of the above embodiment is adapted to indicate the running direction by detecting the geomagnetism, as an alternative which is usable for detecting the running direction during teaching, is means for detecting the steering angle of the front wheel 2 or the angular deflection of the fifth wheel serving as the distance 30 sensor 6.

#### CLAIMS

1. An automatic running work vehicle for performing work while running, comprising means for teaching position data on the outer periphery of the entire area of a work site and thereby automatically producing a running course covering the interior thereof, and means for causing the work vehicle to run the running course under steering control.
2. A work vehicle as claimed in claim 1, wherein said means for producing a running course is so constructed as to calculate and memorize the running course distances of 45 every running process on the basis of the width of the work of the running course while repeating a reciprocating running process to perform work on the ground of the work site from one end of the work site to the other end 50 thereof, further comprising a distance sensor for detecting every running distance and an orientation sensor for detecting orientation information of the work vehicle, said orientation information being detected and sampled in 55 the predetermined running distance during the teaching travel.
3. A work vehicle as claimed in claim 2, further comprising follower sensors for detecting the boundary between a worked area and 60 an unworked area and generating signals so that the work vehicle may automatically travel along the boundary on the basis of the signals and turning of the work vehicle is carried out only under the condition that the memorized 65 distances are in accord with the actual dis-

tances detected per each running process by means of the distance sensor at real time.

4. Automatic running work vehicle, constructed arranged and adapted to operate substantially as hereinbefore described with reference to the accompanying drawings.

Printed for Her Majesty's Stationery Office  
by Burgess & Son (Abingdon) Ltd.—1984.  
Published at The Patent Office, 25 Southampton Buildings,  
London, WC2A 1AY, from which copies may be obtained.